CHAPTER 2:
STUDY AREA

PHYSICAL ENVIRONMENT OF THE LAKE TAHOE BASIN

This study was conducted in the Lake Tahoe basin, located in California and Nevada (Fig. 3). The 880 km^2 (88,000 ha) Lake Tahoe basin, once considered for designation as a National Park, contains the largest alpine lake in North America and is bounded by the crest of the Carson Range on the east and the Sierra crest on the west (Whitney 1979, Landauer 1996, Schaffer 1998). The basin was created by the drop of land between two fault blocks. The Lake Tahoe basin is structurally continuous with the Sierra Valley to the north, but for a volcanic flow separating them. Lake Tahoe itself is 35 km long, 19 km wide, 540 m deep, and occupies 66,500 ha within the basin. Elevation within the basin ranges from approximately 2000 m at the lake to over 3500 m at the highest peaks. Two basic geologic rock types occur in the basin: volcanic and granitic. During the last 65 million years, the area experienced volcanism, faulting, and glaciation, resulting in the creation of Lake Tahoe and the surrounding mountainous terrain.

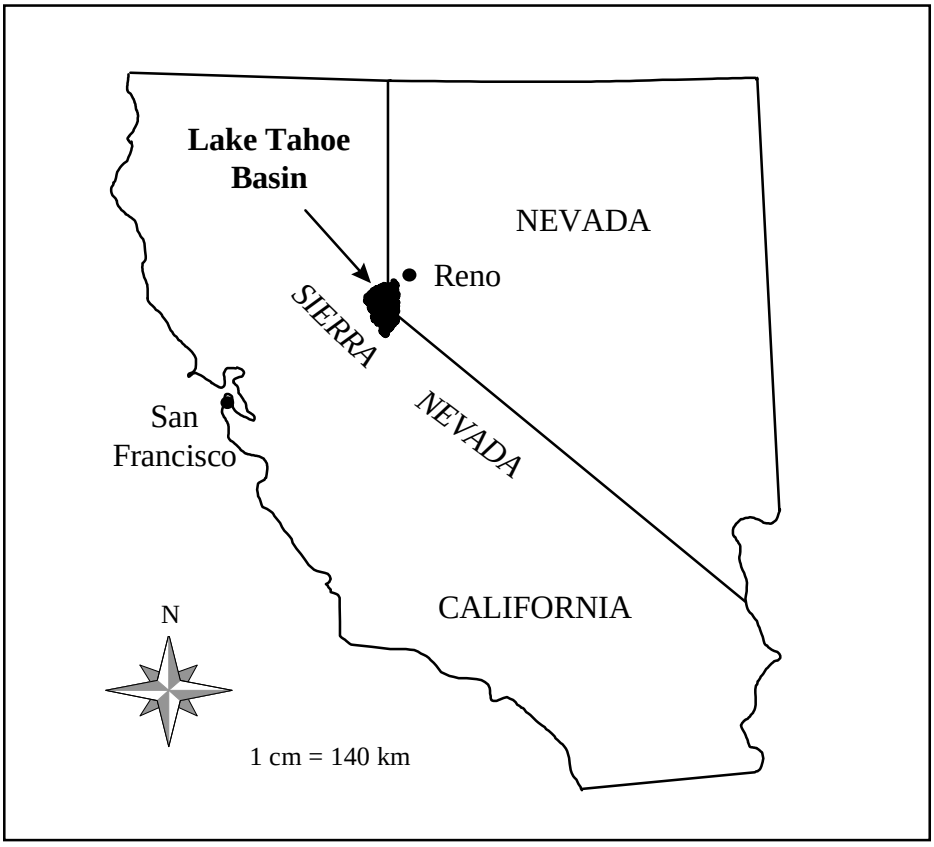

FIG. 3. Location of the Lake Tahoe basin.

Climate within the basin varies greatly between seasons and around the basin. Temperature ranges in the basin are typically around 80° F in the summer and 30° F in the winter, with extremes of over 90° F in the summer and minus 15° F in the winter (Storer and Usinger 1963). Precipitation ranges from 30 to 200 cm per year around the basin, increasing from Lake Tahoe to

the surrounding ridges, and reaching its highest levels along the crest of the Sierra Nevada mountains forming the western border of the basin (TRPA and USDA 1971, Daly 1995, Daly and Johnson 1999).

The Lake Tahoe basin has 53 major watersheds, with a total of over 500 km of perennial streams (USGS 1994) (Appendix 1). The 53 watersheds vary in many characteristics, including elevation, size, stream order, geology, and disturbance. Watersheds range in size from 1 to 73 km^2, range in elevation from 2100 to 3500 m, and range in stream order from 1 to 3. The largest watershed is the Upper Truckee Watershed, which serves as the primary inlet for Lake Tahoe. Fifteen dams exist within the basin (USDA 1988). Most of the dams are associated with preexisting lakes (including Lake Tahoe), and are intended to increase the size of the lakes or to generate power.

Watersheds with different orientations around the basin vary greatly in topography and precipitation (TRPA and USDA 1971, Daly 1995). Watersheds on the west side of the basin are steep, rise 1000 to 1500 m above the lake, and receive an average annual precipitation of 180 to 200 cm. In contrast, watersheds on the east side of the basin are less steep, rise 600 to 1000 m above the lake, and receive an average annual precipitation of 90 to 100 cm. Watersheds on the north side of the Lake Tahoe basin are transitional between west and east, with intermediate steepness, rise, precipitation, and plant community composition. Watersheds on the south side of the basin are also intermediate in precipitation and rise, but they are the most gradual in slope because the rim of the basin is farther from the lake on the south end. As a result, watersheds on the south side of the basin are the largest and have high diversity in channel morphology toward their mouths relative to watersheds located elsewhere in the basin.

NATURAL HISTORY OF THE LAKE TAHOE BASIN

The taxa and their assemblages occurring within the basin represent a biological synthesis created by the operation of physical and biological processes operating at a range of spatial scales. The biota of the Earth have been subdivided many different ways by phytographers and zoogeographers (e.g., Holdridge 1947, Shelford 1963, Kuchler 1964, Udvardy 1969, 1975, Bailey et al. 1994, Omernick 1995). Blondel (1987) outlined the 3 primary space-by-time scales at which biota and the processes that operate on them can be viewed and discussed: the local scale, at which ecological processes operate and autecology and community ecology can be studied; the regional scale, at which smaller-scale manifestations of evolutionary processes (e.g., allopatric and sympatric speciation) and historical biogeography can be studied; and the continental and intercontinental scales, at which larger-scale manifestations of evolutionary processes (i.e., evolution of higher taxa) and paleobiogeography can be studied. Discussions of processes operating to create the present flora and fauna of the basin invoke the local and regional scales.

The Lake Tahoe basin is a biogeographically complex environment. It is located on the east–west boundary of 2 major biogeographic provinces (the Sierra and the Great Basin; Udvardy 1975), and in the vicinity of the north–south juncture of 4 smaller-scale bioregions (Mono-Inyo to the southeast, South Sierra to the southwest, North Sierra to the northwest, and Modoc Plateau to the north; Welsh 1994). The location of Lake Tahoe basin at this confluence of biogeographic zones results in a diversity of environmental conditions and a unique array of flora and fauna around the basin, as well as some distinct distributions of biota around the basin. The most pronounced differences in biota would be expected to occur between the west and east sides of the basin, coinciding with the boundary between the 2 major biogeographic provinces: the Sierra province on the west side and the Great Basin province on the east side of the basin.

In the following section, descriptions of each taxonomic group are provided, including a general description of the biota and their biogeographic influences.

Vertebrates

Based on a review of the primary sources of data for the basin, Manley et al. (2000) determined that 312 vertebrates currently occur in the Lake Tahoe basin. This total consists of 217 birds and 59 mammals, with the remainder consisting of amphibians (n = 5), reptiles (n = 8), and fish (n = 23).

Birds

Of the 149 native bird species considered extant and regularly occurring in the Lake Tahoe basin (Manley et al. 2000), 44 (30%) are associated with riparian conditions to some degree. Therefore, a significant proportion of the native bird fauna in the Lake Tahoe basin is directly affected by riparian conditions. The diversity of aquatic habitats in the basin provides for a variety of aqua-dependent and riparian-associated birds (Orr and Moffitt 1971), most of which are short or long-distance migrants (Zeiner et al. 1990a). The basin's most common species of aqua-dependent birds include Mallard (*Anas platyrhyncos*), Canada Goose (*Branta canadensis*), Common Merganser (*Mergus merganser*), Spotted Sandpiper (*Actitis macularia*), and Killdeer (*Charadrius vociferus*). Less common residents include Eared Grebe (*Podicepts nigricollis*), Redhead (*Aythya americana*), and Wilson's Phalarope (*Phalaropus tricolor*). Several species of gulls and terns have been observed in the basin, the most common being Forester's Tern (*Sterna forsteri*), Ring-billed Gull (*Larus delawarensis*), and California Gull (*Larus californicus*). Several species of birds occupy primarily riparian areas in the basin, including Wilson's Warbler (*Wilsonia pusilla*), Warbling Vireo (*Vireo gilvus*), and Song Sparrow (*Melospiza melodia*). Six species of swallows and 3 species of blackbirds, all of which concentrate near water (Ehrlich et al. 1988), occur in the basin as well.

In addition to native fauna, 5 exotic bird species are known to occur, including 2 game species (Turkey [*Meleagris gallopavo*] and California Quail [*Callipepla californica*]), and 3 other species (European Starling [*Sterna vulgara*], House Sparrow [*Passer domesticus*], and Rock Dove [*Columbia livia*]) (Manley et al. 2000). The Brown-headed Cowbird (*Molothrus ater*) was considered a native species in this study, even though it is considered by some to be a type of exotic (Cox 1999). The Brown-headed Cowbird is native to the North American Great Plains, but has greatly expanded its range in response to human-induced landscape changes (Cox 1999). The Brown-headed Cowbird was considered native because it is native to North America and has expanded its range without the direct intervention of humans (i.e., introductions) (Cox 1999), unlike the 5 species considered here as exotics.

Birds are relatively mobile, and therefore their regional distributions are more limited by environmental conditions than physical barriers. The Lake Tahoe basin contains an abundance of fresh water, a scarce commodity in the Great Basin province (Ryser 1985). Therefore, bird species typically associated with the Sierra province venture into the Great Basin province on the east side of the basin. Few Great Basin specialists occur in the basin, and those that do are generally restricted to the east side.

Mammals

Fifty-nine species of native mammals are known to occur currently in the Lake Tahoe basin (Manley et al. 2000). They consist of 6 orders with varying numbers of members: 1 ungulate (Artiodactyla), 13 carnivores (Carnivora), 10 bats (Chiroptera), 5 insectivores (Insectivora), 5 hares (Lagomorpha), and 25 rodents (Rodentia). Rodents are the most abundant order, comprising over 40% of all species. Of the 59 species, 31 (53%) are associated with riparian

conditions to some degree. Eleven are considered riparian dependent, and an additional 20 species are considered riparian associates, based on Graber's (1996) analysis (with a few adjustments based on local conditions). Thus, over half of the native mammal fauna in the Lake Tahoe basin is directly affected by riparian conditions. In addition to natives, 5 exotic mammals are known to occur, including 1 riparian dependent species (beaver [*Castor canadensis*]) and 4 domestic species (cow [*Bos* sp.], horse [*Equus* sp.], domestic dog [*Canis familiaris*], and domestic cat [*Felis domesticus*]).

Mammals in the basin, with the exception of bats (Chiroptera), are primarily relegated to quadrupedal locomotion. Topographic relief and harsh environmental conditions (including human disturbances) provide a greater barrier to mammals than birds, which should result in mammalian fauna reflecting both habitat conditions and biogeographic influences. Hall (1995) differentiated 5 faunal areas to describe major shifts in distribution among mammal species occurring in Nevada. The Lake Tahoe basin and its immediate vicinity was identified as its own faunal area (the Sierra Nevada area) because it contained 12 species characteristic of the Sierra province that did not occur in any other location in Nevada (Hall 1995). Conversely, species characteristic of the Great Basin province (and other provinces containing desert environments) occur in the Lake Tahoe basin, such as desert woodrat (*Neotoma lepida*) and least chipmunk (*Tamias minimus*) (Hall 1995).

Amphibians

Four native amphibian species are considered regularly-occurring in the Lake Tahoe basin: long-toed salamander (*Ambystoma macrodactylum*), Pacific treefrog (*Hyla regilla*), western toad (*Bufo boreas*), and mountain yellow-legged frog (*Rana muscosa*) (Manley et al. 2000). In addition, 1 exotic species, the bullfrog (*R. catesbeiana*), occurs in the basin. Each of these species is obligately aquatic for at least one of its life stages; several (long-toed salamander, Pacific treefrog, and western toad) breed in water and then use terrestrial habitats after metamorphosis. Thus, all amphibians in the basin are directly affected by riparian conditions.

Reptiles

Eight native reptile species occur in the basin (Manley et al. 2000). Four of these, the 3 species of garter snake (*Thamnophis* spp.) and the rubber boa (*Charina bottae*), are considered dependent or associated with riparian ecosystems (Graber 1996). The garter snakes can regularly be encountered in aquatic ecosystems.

Invertebrates

Over 5000 species of invertebrates are suspected to occupy the Lake Tahoe basin, including terrestrial and aquatic insects, mollusks, spiders, and crustaceans (Storer and Usinger 1963). Based on numerous sources, Manley et al. (2000) estimated that 379 families of invertebrates potentially occur in the basin. However, data on the composition of invertebrate fauna is fragmentary and has not been summarized.

Biogeographic data on invertebrate fauna are largely lacking at the scale of the Sierra Nevada (Kimsey 1996), however Powell and Hogue (1979) proposed 6 faunal provinces for insects in California. The Lake Tahoe basin falls on the boundary between the Sierran and Great Basin faunal provinces. The Sierran province is described as having the greatest diversity in habitats and the highest richness in insect species of the 6 provinces. They also note that a high proportion of the species in the Sierran province range into adjacent provinces, but that many insects are found only in this province. The Great Basin province is described as uniform in character, rich in species, and relatively distinct from other parts of California's fauna. These same patterns should generally apply to higher taxonomic levels, but with fewer distinctions

among provinces. In addition to terrestrial environments, it appears that the freshwater ecoregions, as proposed by the World Wildlife Fund and described in Ricketts et al. (1999), also reflect a distinction between the Sierra Nevada and the Great Basin, as defined by the demarcation between the Coastal complex and the Great Basin complex within the Pacific Bioregion.

Vascular Plants

The Sierra Nevada is renown for its diversity of plants and high number of endemic species (Stebbins and Major 1965, Raven and Axelrod 1978, Weeden 1996). Similarly, the Lake Tahoe basin has a diversity of vascular plant species and communities (Smith 1973, 1983, Elliott-Fisk et al. 1997, Graf 1999, Manley et al. 2000). A total of approximately 1300 vascular plant species potentially occur in the Lake Tahoe basin, with 1077 species having been confirmed (Manley et al. 2000). Vegetation communities within the basin can be classified into 4 vegetation zones: lower montane, upper montane, subalpine, and alpine (Whitney 1979). The lower montane vegetation zone extends from approximately 650 to 2000 m, and it only occurs on the lower slopes of the basin near the lake. It is characterized by ponderosa pine (*Pinus ponderosa*) and white fir (*Abies concolor*), with some incense cedar (*Calocedrus decurrens*), and sugar pine (*Pinus lambertiana*). The upper montane vegetation zone occupies the majority of the basin, generally occurring between 2000 and 3000 m. The primary tree species are Jeffrey pine (*Pinus jeffreyi*), red fir (*Abies magnifica*), western white pine (*Pinus monticola*), lodgepole pine (*Pinus contorta*), and California juniper (*Juniperus californica*). The subalpine vegetation zone generally occurs above 3000 m; characteristic species include whitebark pine and mountain hemlock. Within the subalpine zone, vegetation shifts from continuous forest cover in the lower portion to sparse clusters of stunted trees at the uppermost extent of its elevational range. Meadows occur throughout the basin, but occupy less than 1% of the basin land area (USDA 1991a). The alpine zone is rare within the Lake Tahoe basin, and generally occurs over 4000 m outside the basin. It consists of small arrays of shrubs and herbs. Limited information exists about the non-vascular plants in the basin (Manley et al. 2000).

Plant species distributions have been used as the basis for the delineation of many faunal regions, and therefore it is not surprising that plant regions are very similar to faunal regions. Hickman (1993) recognized 3 floristic provinces and 10 floristic regions within California, based primarily on vegetation, climate, geology, and topography. The boundaries of the provinces coincide closely with Sawyer and Keeler-Wolf's (1995) regions and Bailey's (1994) ecoregions. The California Floristic Province is the largest of the 3 provinces, occupying approximately 2/3 of the state. The Lake Tahoe basin occurs within the Sierra Nevada region of the California Floristic Province, bordered on the east by the Great Basin Floristic Province. The Sierra Nevada region is characterized by montane and subalpine conifer forests, whereas the Great Basin Province is characterized by sagebrush steppe and pinyon–juniper woodland. Specific plant associations were not provided, however descriptions of subsections of Bailey's (1994) classification provides additional information on plant species distributions.

Macrofungi

Macrofungi are defined as fungi that form macroscopic growth forms (lichen) or fruiting-bodies (primarily basidiomycetes), such as jelly fungi, puffballs, and bird's nest fungi (Dix and Webster 1995). Macrofungi are generally better known because they are more readily detected than microfungi. Fungi with macroscopic growth forms and fruiting-bodies belong to a diverse array of taxonomic groups (orders) and access a diversity of nutritional sources (Dix and Webster 1995).

Data on the composition of macrofungi in the Sierra Nevada are sparse. Desjardin (1997) compiled lists of species, genera, and families known to occur in the Sierra Nevada, but recognized that it was far from a comprehensive accounting the macrofungi for the area. Data on the macrofungi of the Lake Tahoe basin are similarly sparse and incomplete. Surveys of lichen in Desolation Wilderness by Ryan (1990) are the only known formal surveys for lichen or other macrofungi in the Lake Tahoe basin. A list of potentially occurring macrofungi taxa was compiled by Manley et al. (2000), and consisted of 339 genera, 60 of which have been documented as occurring in the basin.

The distribution of macrofungi in the Sierra Nevada and Great Basin is generally unknown. No fungal regions have been identified for macrofungi in general, however discussions of lichen distributions in California can be found in Hale and Cole (1988). Hale and Cole (1988) suggested that lichen richness is positively correlated with rainfall in the Sierra Nevada, and that vegetation types serve as a crude, but currently most effective approximation of where lichen genera and species occur. The montane and subalpine forests characteristic of the basin are home to genera such as Bryoria, Cladonia, Letharia, Tuckermannopsis, Ahtiana, and Melanelia. The other distinct environment in the basin where lichen occur is the alpine fell-field (Hale and Cole 1988). This zone occurs above tree line, and here lichen such as Physcia, Pseudophebe, and Rhizoplaca grow on exposed rocks. Few lichens are restricted to any one of these environments.